United States
Department of
Agriculture

Economic
Research
Service

International
Economics
Division

Sudan's Irrigated Subsector

Issues for Policy Analysis

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SUDAN'S IRRIGATED SUBSECTOR: ISSUES FOR POLICY ANALYSIS. By Brian C. D'Silva. International Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington, DC 20005-4788. September 1986. ERS Staff Report No. AGES860811.

ABSTRACT

Sudan's present economic crisis suggests a need for evaluating the role of its irrigated subsector, the largest in Sub-Saharan Africa, in agricultural and economic recovery. The present system of production in the subsector results in a suboptimal use of imported inputs like fertilizer. The need for such an evaluation centers on changes in cropping patterns, in institutions, and in production technologies that will help generate foreign exchange earnings, Government revenues, and farm sector income.

Keywords: Irrigation, resource use, foreign exchange earnings, agricultural policies, Sudan.

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FOREWORD

This report is the second in a series of research reports on the agricultural sector of Sudan. Much of the data and information used in this and subsequent reports were collected when the author was resident at the University of Khartoum, Sudan, under a Ford Foundation grant. This report presents an overview of Sudan's irrigated subsector and identifies key issues for policy analysis. Reports that follow will examine these issues in greater detail.

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INTRODUCTION

Sudan's agricultural productive capacity comes from its potentially cultivable area, among the largest in Sub-Saharan Africa, the diversity of its agriculture with three distinct subsectors (irrigated, mechanized rainfed, and traditional rainfed, each producing export and food crops), and its being the largest irrigated area in Sub-Saharan Africa. An analysis of factors affecting the productive capacity of Sudanese agriculture has implications for changes within the wider context of Sub-Saharan Africa because:

- Sudan illustrates factors affecting supply response in traditional and modern agriculture.
- Sudan has some of the most modern production technology embodied in its irrigated subsector. Hence, analyzing the subsector provides insight into the interaction between technological change and institutional factors as it relates to productive capacity.
- An examination of Sudan's tradeoffs in production choices among export crops like groundnuts and cotton is important in understanding a major world producer's response to changing international prices. For example, Sudan must react to the effects of the 1985 U.S. Food Security Act or changes in world cotton prices and to foreign exchange constraints, issues facing other Sub-Saharan countries.
- The policy and institutional factors leading to an inefficient allocation of resources need to be identified to evaluate Sudan's potential for competitive performance in world cotton markets.
- Sudan, like other Sub-Saharan countries, has undertaken policy changes at the behest of donors (both bilateral and multilateral), and it is necessary to understand the reasons for their less than complete success.

The focus of this report is on the role of the irrigated subsector in Sudan's agricultural economy and issues for policy analysis in the subsector.

IRRIGATED SUBSECTOR OF SUDAN

Sudan's irrigated subsector consists of irrigated schemes 1/ covering over 4.5 million feddan, 2/ dominated by the 2.1 million-feddan Gezira scheme, which is irrigated by gravity flow from the Blue Nile (fig. 1). In addition, parastatal 3/ and private pump schemes exist along the Blue, White, and Main Niles. The structure and organization of production in the irrigated subsector vary from large schemes like Gezira to the pump schemes along the Blue and White Niles. Such schemes are organized as parastatals and involve a relationship between the Government, the scheme corporation, and individual tenants. Some of the pump schemes along the Blue and White Niles are operated by individuals, with the Government having minimal decisionmaking powers in their operation. Table 1 shows the major irrigated schemes in Sudan, their location, area covered, and principal crops grown. The Blue Nile feeds much of the area in the subsector.

As seen in table 1, cotton is grown in most of the irrigated schemes, and over 90 percent of Sudan's cotton production and exports come from the irrigated subsector. Sorghum is grown within the irrigated schemes primarily for onfarm consumption; groundnuts are for export and wheat and sugarcane are produced as import substitutes and consumed within the country.

The changing share of national production attributable to the irrigated subsector for cotton, sorghum, and groundnuts is shown in figures 2-4. Cotton production, Sudan's major source of export earnings, declined by over 50 percent in the latter half of the seventies. Changes in institutional arrangements within the irrigated schemes and rehabilitation of these schemes led to 1984 production levels reaching those of the early and midseventies. But Sudan has had problems marketing its cotton, and foreign exchange earning increases have not been commensurate with production increases.

Because over 70 percent of Sudan's sorghum is produced in the rainfed areas, the variability in rainfall causes variability in this production. Sorghum production in the irrigated areas prevented Sudan's food situation in 1984/85 from being much worse (4). 4/ While groundnut production has shown a decline since the seventies, the share of the irrigated subsector increased, primarily due to decreased production in the traditional rainfed subsector. The decline in overall national production of groundnuts led to Sudan's losing its position in the world groundnut market. As recently as 1982, Sudan was the third largest exporter of groundnuts in the world, after the United States and China. In 1985, Sudan's groundnut production reached its lowest level in two decades.

Sudan is suffering from a severe economic crisis and in 1984-85 experienced a major food crisis. While the food crisis was the result of a 3-year drought, the economic crisis has its roots in the oil price increases and domestic policies enacted in the seventies. This crisis has been exacerbated by a

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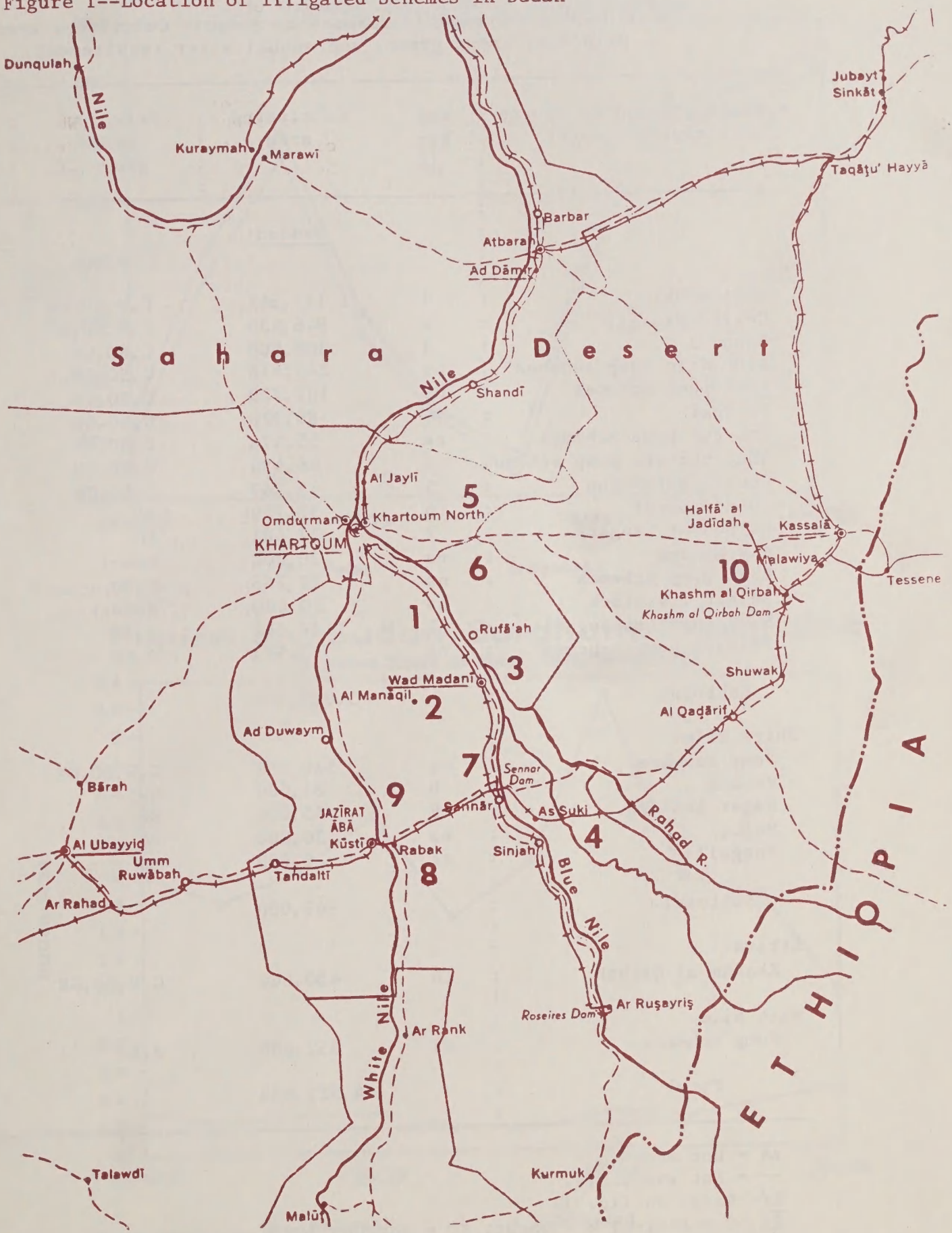
1/ A scheme is a sizable area of irrigated crop production under centralized management.

2/ 1 feddan = 1.03 acres.

3/ Parastatal (adjective and noun) refers to government involvement in an activity outside government.

4/ Underscored numbers in parentheses cite sources listed in References.

Figure 1--Location of Irrigated Schemes in Sudan



Note: For scheme numbering, see table 1. Map courtesy of Department of State

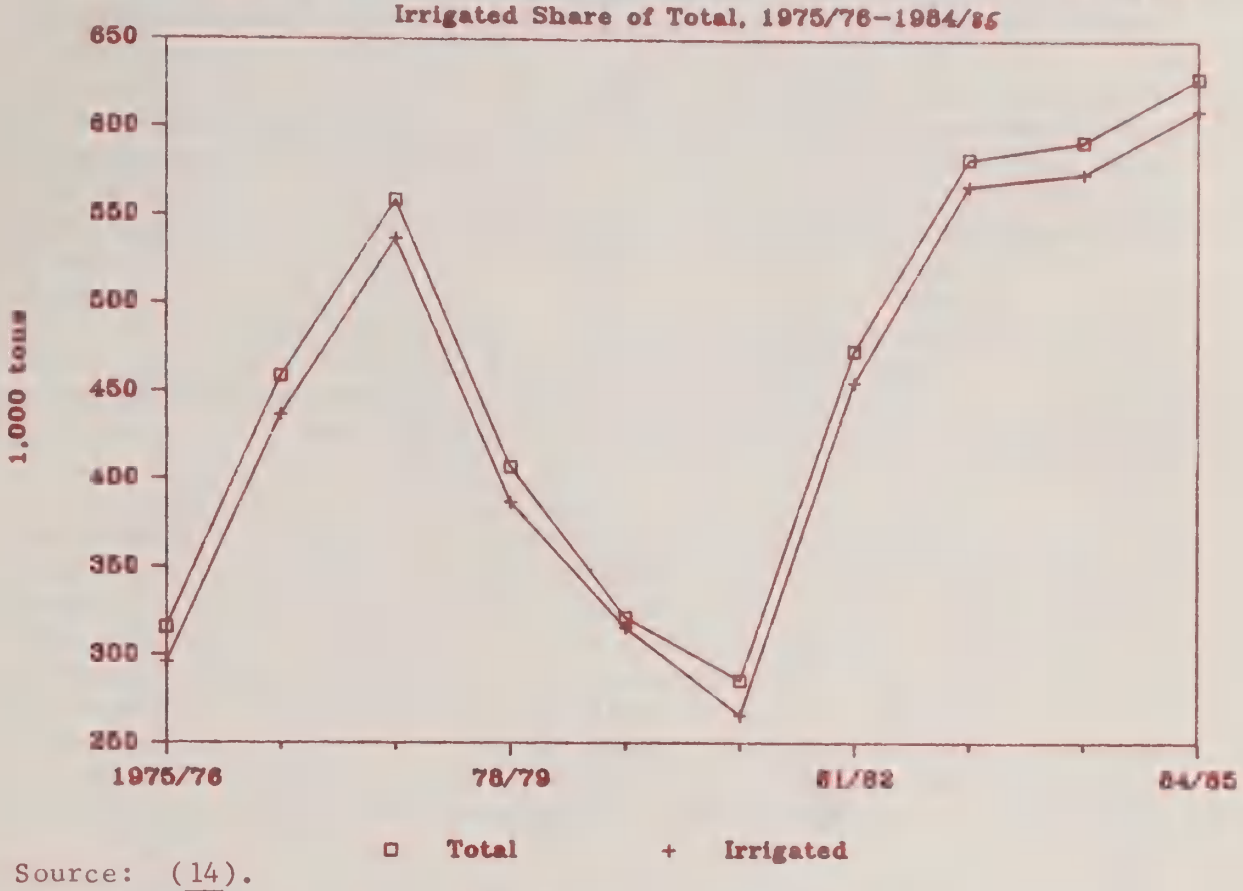
Table 1--Major irrigated schemes in Sudan: Cultivated area, principal crops grown, and annual water requirement

Schemes grouped by source of irrigation water	Map key 1/	Cultivated area	Principal crops grown 2/	Annual water requirement
		Feddan		Million m^3
Blue Nile:				
Gezira-Main	1	1,135,362	C,W,SO,GN	4,000
Gezira-Managil	2	946,330	C,W,SO,GN	3,600
Rahad I	3	300,000	C,SO,GN	1,139
Blue Nile pump schemes	ns	245,418	C,SO,GN	--
BNAC pump schemes	ns	103,729	C,SO,GN	--
Es Suki	4	86,920	C,SO,GN	330
Private pump schemes	ns	55,478	C,SO,GN	165
BNAC private pump scheme	ns	46,490	C,SO,GN	--
Guneid extension	5	45,367	C,SO,GN	180
Guneid sugar	6	38,720	SC	230
NW Sennar (sugar)	7	32,481	SC	388
Abu Na'ama	ns	30,000	Kenaf	100
BNAC pump schemes	ns	22,256	C,SO	--
Seleit livestock	ns	20,000	Fodder	--
NW Sennar (nonsugar)	7	16,661	C,SO	--
Private pump schemes	ns	7,971	C,SO	--
Subtotal		3,029,454		11,018
White Nile:				
Pump schemes	ns	530,000	C,W,SO,GN	--
Kenana	8	81,000	SC	--
Hagar Asalaya	9	35,000	SC	--
Melut	ns	30,000	SC	--
Mongalla	ns	20,000	SC	--
Subtotal		969,000		2,231
Atbara:				
Khashm al Qirbah	10	450,000	C,W,SO,GN	1,180
Main Nile:				
Pump schemes	ns	352,000	W,SO	1,200
Total		4,527,454		15,629

ns = Not shown.
-- = Not available.
1/ Refer to fig. 1.
2/ C = cotton; W = wheat; SO = sorghum; GN = groundnuts; SC = sugarcane.

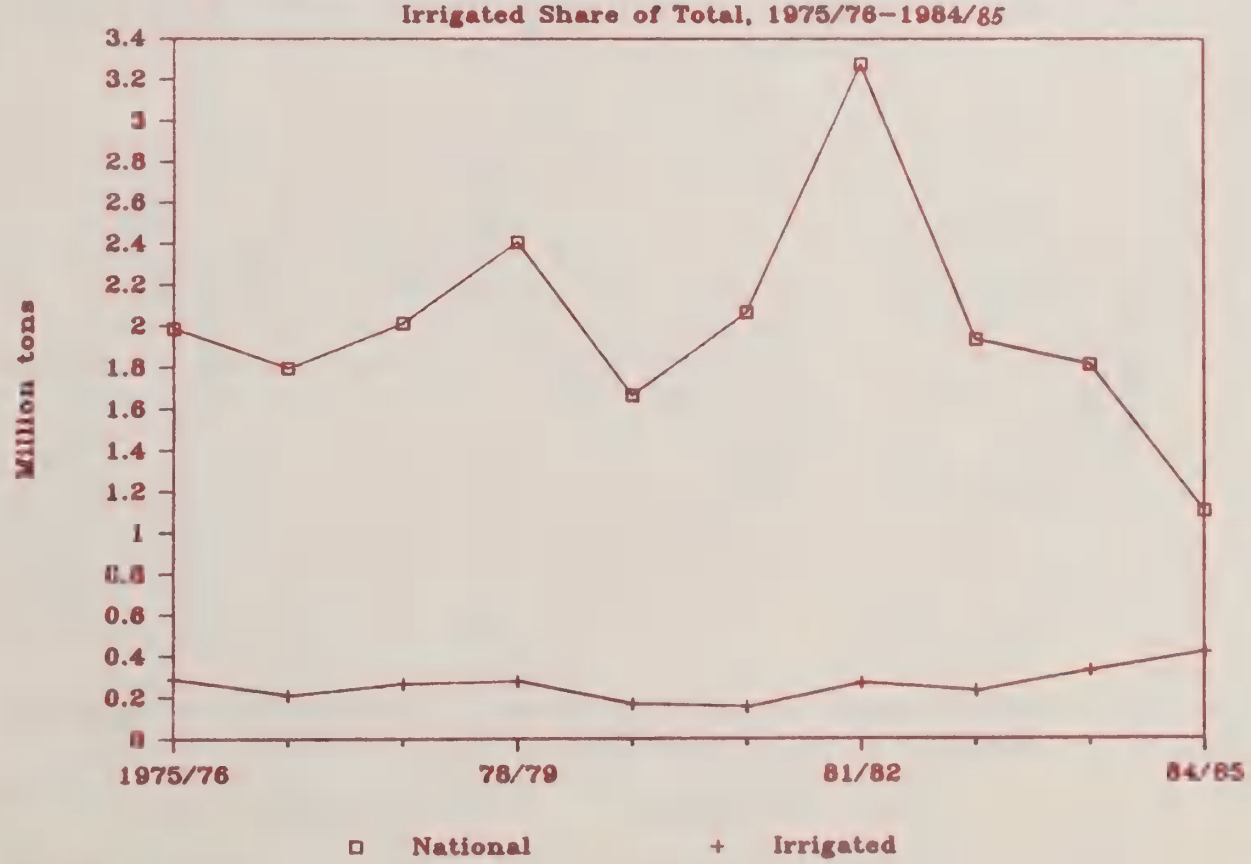
Source: (14).

Figure 2: Sudan Cotton Production



Source: (14).

Figure 3: Sudan Sorghum Production



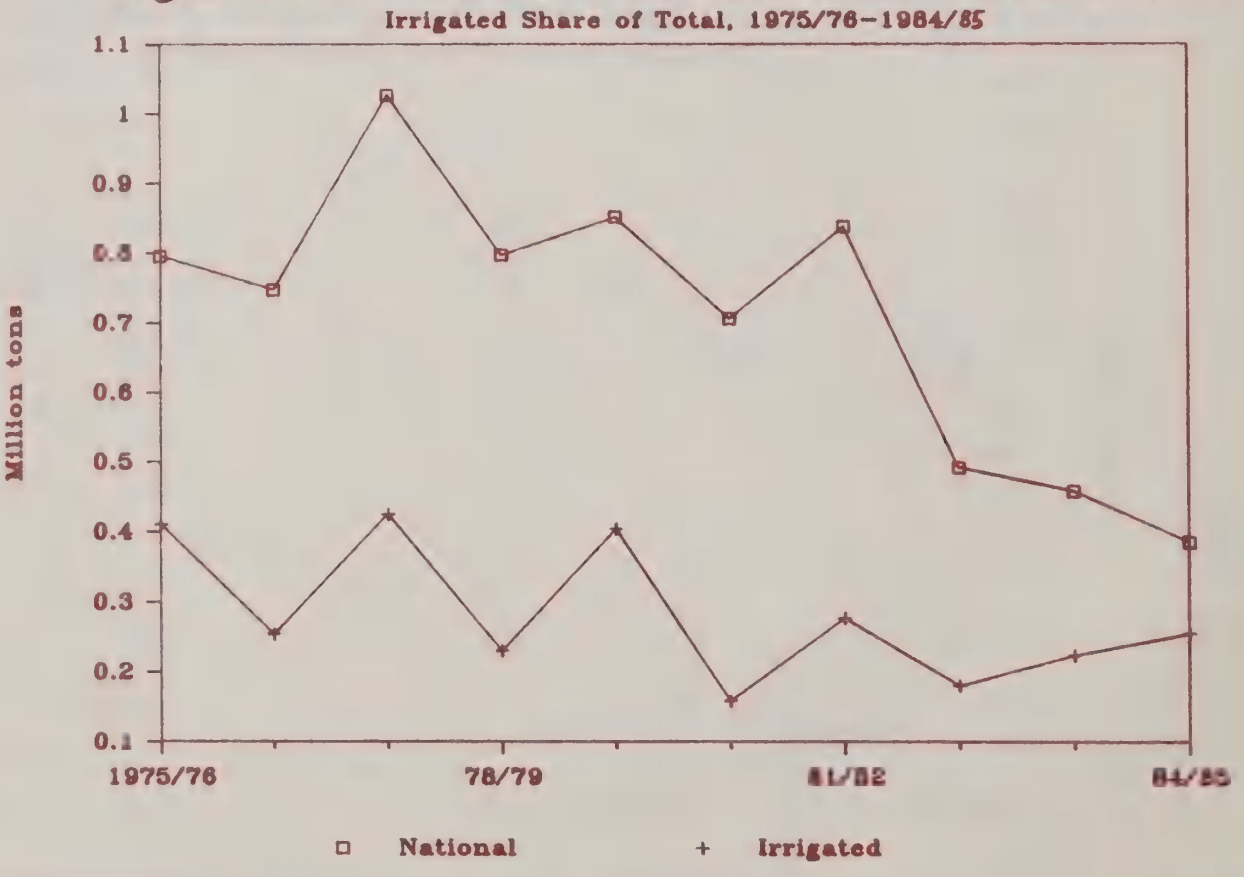
Source: (14).

3-year civil war. This led to Sudan's accumulating an external debt of over $9 billion and debt service payments of over $1 billion in 1985. 5/

In the past, the irrigated subsector was viewed as being able to generate foreign exchange for the country, primarily due to its historic role in the production of cotton for export. Furthermore, an infrastructure already exists within the irrigated subsector that facilitated transportation of inputs and outputs between the major irrigated schemes and the country's only port in Port Sudan. Hence, national development plans and recent public sector investment programs focused on the rehabilitation of productive resources in the irrigated subsector. Assistance for these projects came primarily from the World Bank and led to increased yields of cotton in schemes like Gezira between 1981/82 and 1984/85. However, a changing world market of cotton exports, the after-effects of a drought, and a changing macroeconomic environment faced the country.

In spite of a continuing economic crisis, 1985 also saw the largest Sudanese sorghum crop in history, with an increase from 1.2 million metric tons in 1984/85 to 3.6 million tons. Hence, Sudanese agriculture also demonstrated the conditions under which its production potential could be realized. These conditions were price incentives for producers (even if they were drought induced), adequate rains, and fuel for farm operations. Because the 1985 sorghum production increases occurred primarily in the mechanized rainfed subsector, the role of the irrigated subsector needs further analyzing, especially in relation to its potential as a source of both food and export crops.

Figure 4: Sudan Groundnut Production



5/ A detailed discussion of the effects of the drought and the origins of the economic crisis can be found in (4).

Understanding the role and potential of Sudan's irrigated subsector requires an analysis of policy issues important for assessing aggregate supply response, foreign exchange earnings, and input demand of the subsector. These policy issues include cropping pattern changes, technological change, and institutional change in the subsector. An analysis of the above policy issues will focus on the productive capacity of the subsector, its capability to generate increased foreign exchange earnings, and the relationship between the irrigated subsector and the mechanized and traditional rainfed subsectors.

PRODUCTIVE CAPACITY OF THE IRRIGATED SUBSECTOR

The agricultural production potential of the irrigated subsector is dependent upon institutional, technical, economic, and environmental factors. Among institutional factors is the structure of production that has evolved historically with the introduction of irrigation in Sudan. Technical factors are related to the level and intensity of use of mechanical and chemical technologies. Economic factors are related to the structure of incentives, such as relative prices and the transmission of price changes. Environmental factors are related to the availability of irrigation water, the timing of the rains, and soil characteristics of the area.

Institutional Factors

Irrigated agriculture in Sudan, primarily organized as large schemes, first appeared in the twenties to produce cotton for export. Historically, the major irrigated schemes have been the primary source of export earnings for the country and the focus of Government investments in the agricultural sector. These schemes have continually emphasized cotton, with groundnuts, sorghum, and wheat being introduced into the cropping pattern in more recent years.

Due to the major role of the Government in irrigated subsector investment, the structure of production relations was organized so that the Government received a share of net returns from the operation of these schemes. This institutional arrangement, under which most of the schemes operated until 1980/81, was known as the "joint account." 6/ Under this arrangement, net returns from scheme operations were divided among the central Government, the scheme, and the tenants. The tenants' share was then divided among themselves according to their level of production. Figure 5 shows the changing share of net income among the participants for the 1970/71 to 1979/80 period in the Gezira scheme. Under this system, all tenants were guaranteed income from cotton, regardless of their yield level. A criticism of this system was that low-yield tenants benefited at the expense of high-yield tenants. Associated with this form of arrangement was a schedule of responsibilities for production activities in the scheme, such as land preparation, aerial spraying of cotton, and application of fertilizer, and provision of inputs like fertilizer and fuel.

Because cotton was viewed by tenants as a Government crop, the scheme provided credit for labor-intensive cotton operations, like weeding and harvesting. Upkeep of the irrigation network and provision of irrigation water were the

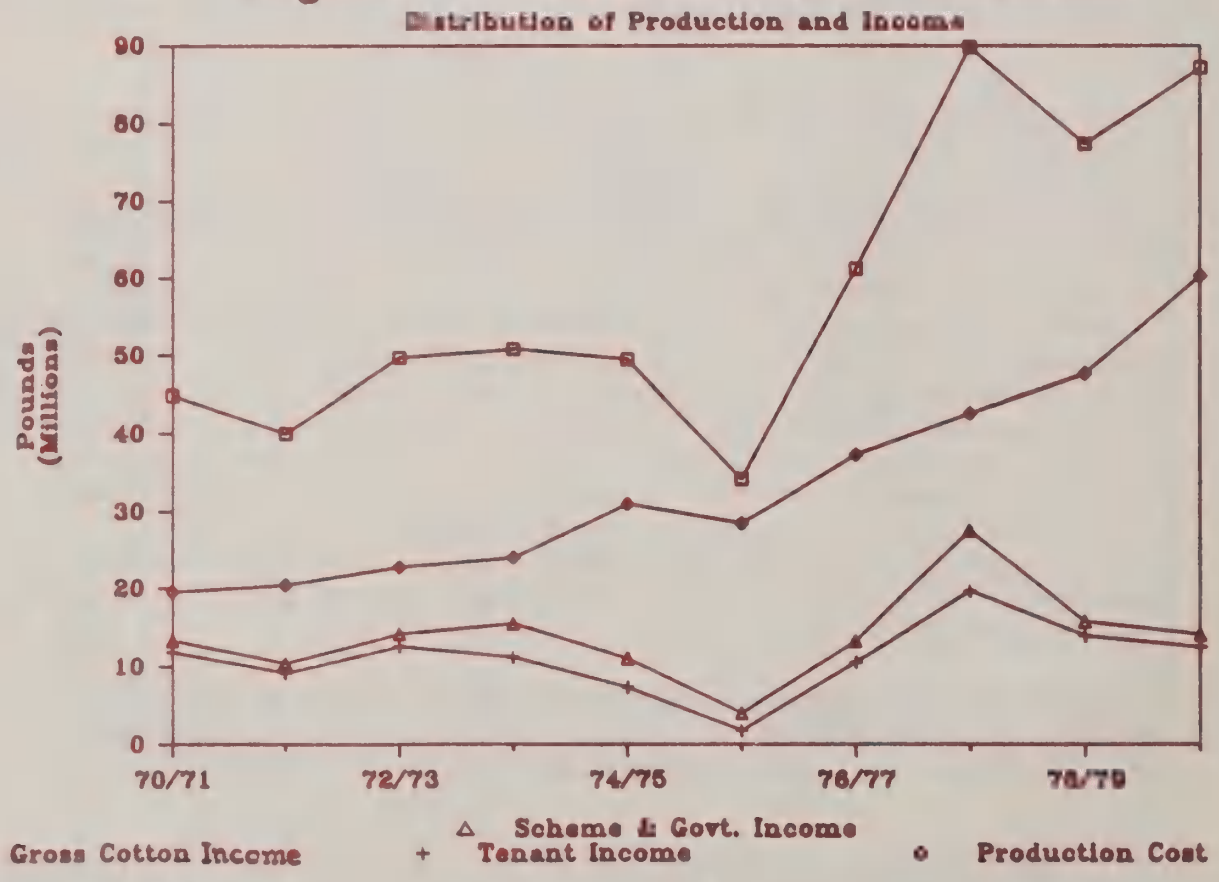
6/ The Rahad Scheme was an exception because it was initiated in 1977/78 under a different institutional relationship known as the individual account.

responsibilities of the Irrigation Ministry. Tenants, however, were responsible for field operations like planting, weeding, and harvesting.

Sudan's cotton production in the late seventies was characterized by declining yields (figs. 6 and 7). This led to a decline in foreign exchange earnings, so a major institutional change was undertaken through the introduction of the individual account system beginning in 1981/82. While the division of responsibilities for production activities between scheme and tenant has not changed under the individual account system, a new method of cost recovery and crop remuneration has begun. In this system, tenants are charged a fixed cost for services provided to them by the scheme. The cost varies by crop and operation. Cotton prices are announced at the beginning of the cotton-picking season, and tenants are paid their net revenues after all the costs of scheme-provided operations have been deducted.

Under this new system, tenants' incomes are related to their productivity. But, as the cost charges are similar for all tenants regardless of their access to inputs like water and land quality, tenants in low-yielding areas are penalized compared with tenants in high-yielding areas of the scheme. Faki has shown that yield differences in the Gezira scheme can be explained by location of tenancies such as the area within the scheme and distance from irrigation canals (6). The introduction of the individual account has led to increased yields of cotton (in the past 5 years) but not necessarily to comparable increased foreign exchange earnings due to problems in cotton marketing and a changing world cotton market. (See (10) for details of the differences between the joint and individual accounts and their impact on tenant incomes.)

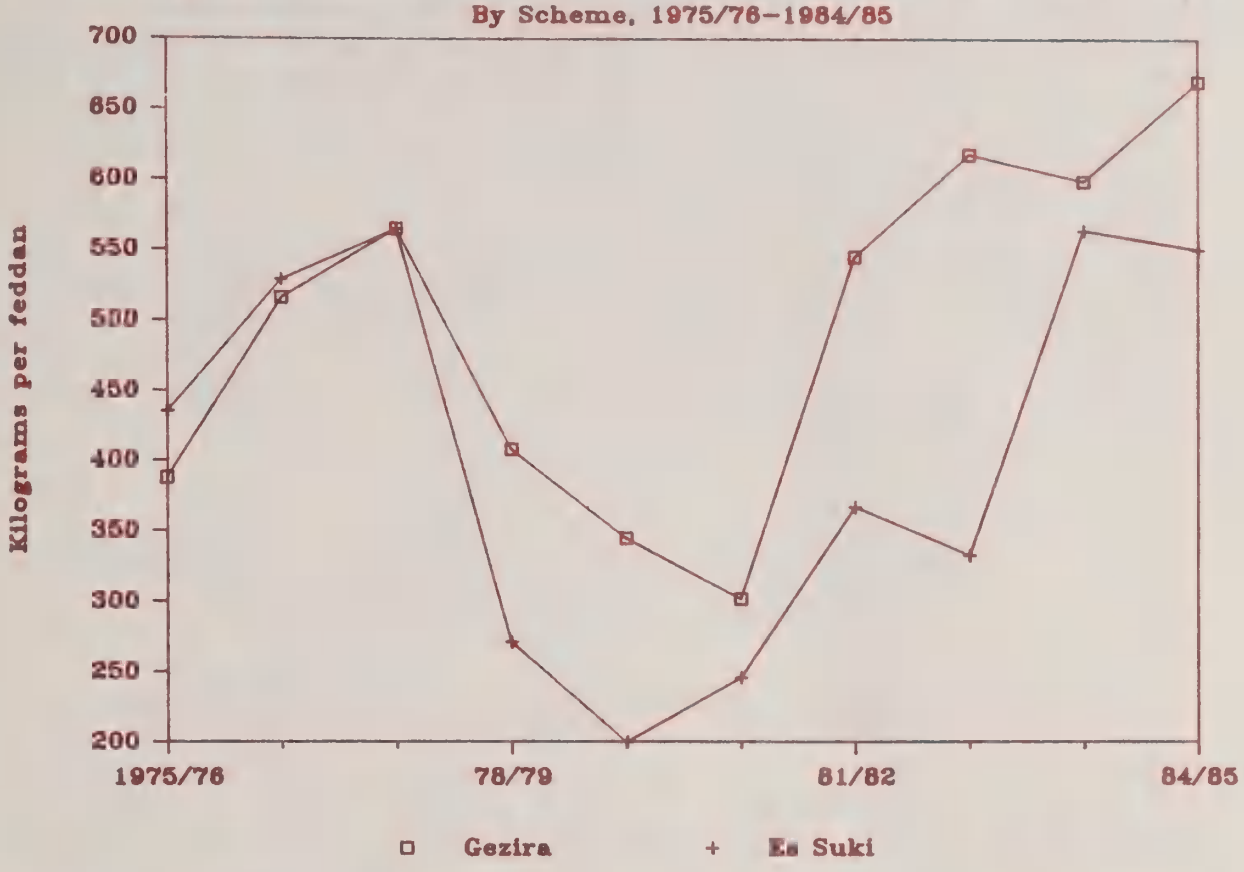
Figure 5: Gezira Joint Account



Source: (14).

Figure 6: ELS Cotton Yield Variability

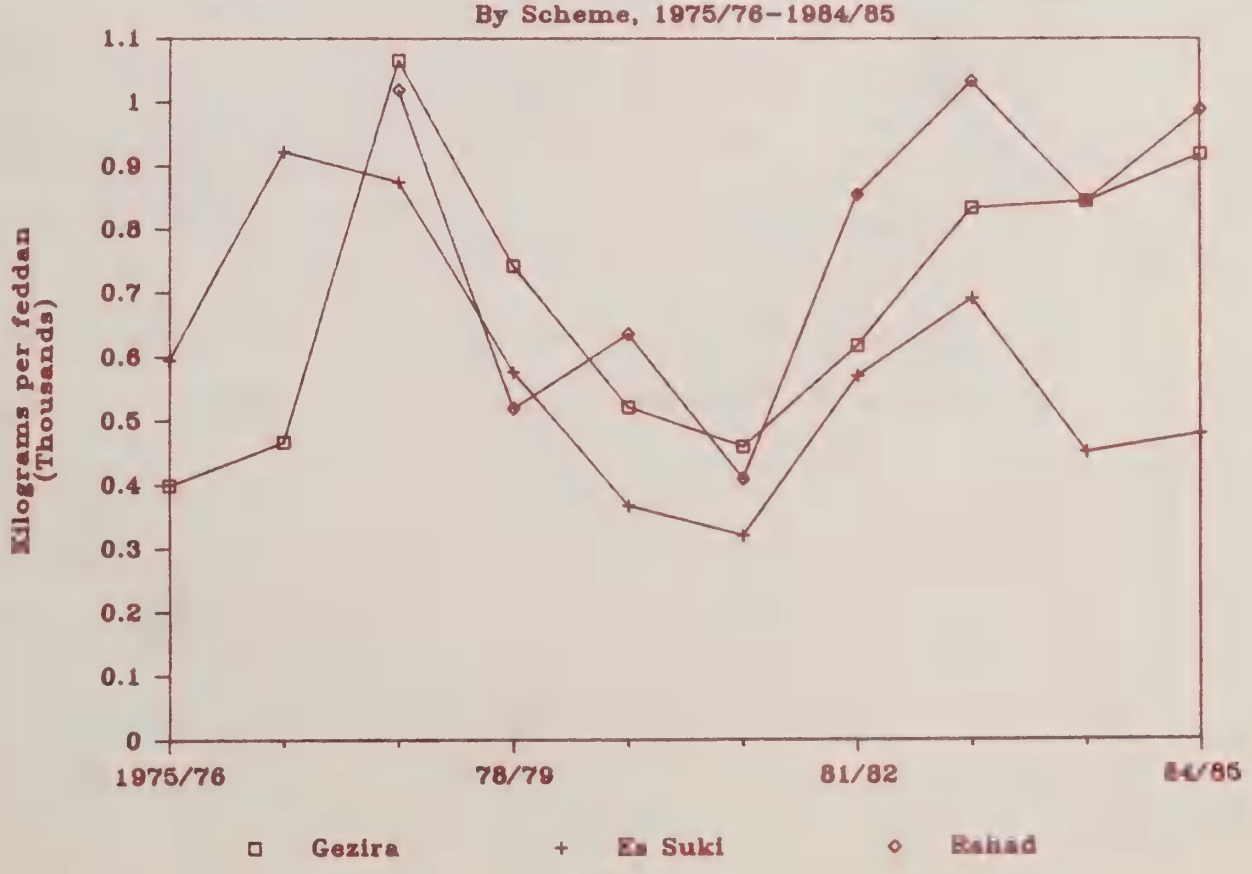
By Scheme, 1975/76-1984/85



Source: (14).

Figure 7: MS Cotton Yield Variability

By Scheme, 1975/76-1984/85



Source: (14).

An important institutional characteristic in large irrigated schemes is the lack of tenant flexibility in decisionmaking concerning areas to be allocated to different crops. Because crop rotations are predetermined at the scheme level, tenants are required to allocate fixed areas of their tenancies to specific crops. For example, in the Rahad scheme, tenants with a 22-feddan tenancy are required to plant 11 feddan to cotton, 5.5 feddan to groundnuts, and 5.5 feddan to sorghum. A rationale for the fixed area allocation is that it facilitates operations that are the scheme's responsibility, for example, land preparation, aerial spraying, and irrigation. Having fixed area allocations also facilitates estimating aggregate production. Scheme management is able to change cropping patterns at the scheme level as a result of changes in environmental and economic conditions, but this does not allow tenants to reallocate their individual tenancy area to different crops in response to changing economic conditions at the farm level. This leads to conflicts between scheme and tenant objectives.

Technical Factors

The level of technology used is an important factor in determining crop productivity in the irrigated subsector. Technologies used vary by scheme, by crop, and by operation. All major preplanting operations in the irrigated subsector are done mechanically, while planting is done by both hand and tractor. Weeding is done by hand or with herbicide. Fertilizer use is restricted to cotton and wheat, and insecticides and pesticides may be used only on cotton. In the Rahad scheme, groundnuts are harvested mechanically and manually but only manually in other schemes. Cotton harvesting is predominantly manual, although mechanical cotton harvesters were introduced in the Rahad scheme but are no longer in use. Table 2 shows the extent of chemical and mechanical technology use for specific operations in the Rahad and Gezira schemes.

Table 2--Extent of chemical and mechanical technology used for specific operations, Rahad and Gezira schemes, 1983/84

Item	Scheme	
	Rahad	Gezira
	Percent	
Cotton area treated with herbicide	68	98.6
Groundnut area:		
Mechanically dug	20	0
Mechanically threshed	38	0
Wheat area mechanically harvested	n.a.	100
Cotton area mechanically harvested	0	0

n.a. = Not applicable.

Sources: (13, 16).

Related to the use of mechanical and chemical technology are issues of their availability and tenant preference. For example, while tenants may wish to use fertilizer on sorghum, they are restricted in its use and, hence, may need to buy it from unofficial channels as the Government controls the importation of fertilizer to meet the estimated needs of irrigated crops like cotton and wheat. In a recent survey of tenant preferences and uses of harvesting technologies in the Rahad scheme, 98 percent of tenants preferred manual harvesting of cotton, while 72 percent preferred mechanical harvesting of groundnuts. The chief reason for manual harvesting of cotton was increased yields and improved quality, both of which led to higher incomes, while higher yields, improved quality, and timeliness of operation were the chief reasons for tenants' preferring mechanical harvesting of groundnuts (16).

Technological factors also affect the timing of operations and, hence, yields. For example, a delay in cotton planting or wheat planting, due to unavailability of tractors or labor, could lead to reduced yields. Similarly, if labor is scarce, use of herbicides could alleviate a potential constraint, preventing a decrease in yields. Table 3 shows the effect of timing of various operations on yield for cotton in the Gezira scheme.

Table 3--Effects of timing and frequency of major operations on yields of cotton, Gezira scheme, 1983/84

Operation	Cotton MS 1/		Cotton ELS 2/	
	Date or number	Yield	Date or number	Yield
		Kantars/ feddan 3/		Kantars/ feddan 3/
Sowing date	July 1	7.8	July 31	4.5
	July 31	7.2	Aug. 15	4.1
Number of irrigations	8	6.7	8	3.7
	9	7.1	9	4.1
	10	8.3	10	4.2
	11	7.4	11	4.8
Harvesting date	Nov. 30	8.0	Nov. 30	--
	Dec. 15	7.2	Dec. 15	--
	Dec. 31	6.3	Dec. 31	5.1
	Jan. 15	4.5	Jan. 15	4.4
	Jan. 31		Jan. 31	4.3
	Feb. 15		Feb. 15	3.5

-- = Not available.
1/ MS = medium staple.
2/ ELS = extra long staple.
3/ 1 kantar = 315 pounds of seed cotton.

Source: (13).

Economic Factors

Economic factors are related to the structure of incentives facing the subsector, its relationship to other subsectors and the macroeconomy, and the transmission of incentives from the subsector level to the farm level. The introduction of the individual account system in 1981/82 for major schemes as discussed earlier was supposed to have a major effect on the structure of incentives. Primarily, it was expected to have enabled schemes to charge tenants costs associated with specific operations for each crop, and because cotton and wheat producer prices would be announced prior to the start of the harvest season, it was expected to act as an incentive to tenants. 7/ This required annual revisions in cotton prices and the costs charged to tenants. The individual account was also viewed as a means of achieving full cost recovery for operations done by the scheme. Under the joint account scheme, revenues were related only to production of cotton, while under the individual account scheme, revenues were related to costs recovered from operations on all crops.

While cotton yields have increased in the Gezira scheme, they could have been higher had rehabilitation of the physical structure of the scheme occurred under the World Bank-financed Agricultural Rehabilitation Program.

Under the present institutional structure of fixed area allocations in major schemes, tenants do not have the flexibility to reallocate area to the different crops in light of changing economic and technical conditions, nor can they reallocate specific resources like fertilizer away from cotton to sorghum in response to changing incentives. This suggests that the Government and the scheme management would need to constantly change prices (input and output) so as to maintain a particular structure of incentives. This may prove difficult because the labor and sorghum markets in the irrigated schemes operate free of scheme intervention. Annual pricing exercises are, however, conducted for scheme-provided inputs, cotton, and wheat, leading to revised cost estimates and output prices for these commodities for tenants. But in the past 3 years, the Sudanese economy has experienced annual rates of inflation of 30-70 percent, a series of devaluations, and a changing world market for medium staple cotton. Hence, the manner in which macroeconomic changes are translated into farm-level incentives become important questions in analyzing the structure of incentives and their impact on productivity in the irrigated subsector.

Devaluations have the effect of increasing the domestic price of imported commodities, making exports competitive in world markets, and serving as an incentive to domestic producers of exportable commodities. For instance, between 1982/83 and 1983/84, costs of insecticides and herbicides increased by over 100 percent for tenants in the Rahad scheme, but fertilizer costs increased by only 15 percent while cotton prices increased by 20 percent. During this period, inflation hit 40 percent and the Sudanese pound was devaluated by 45 percent, suggesting that the effects of the devaluation were not transmitted fully or evenly.

The structure of incentives also affects labor use and the intensity of nonlabor input in the irrigated subsector. As mentioned earlier, laborers

7/ In addition, wheat producer prices are now based on import parity, reflecting an incentive for tenants.

weed and harvest most crops, especially cotton. A major perceived problem has been a shortage of hired labor for cotton picking because wages are low in the irrigated subsector. This perceived shortage has also led to the introduction of mechanical cotton and groundnut harvesters in the Rahad scheme. However, tenants' preference for use of mechanical cotton harvesters declined to the point where, in 1984/85, no mechanical cotton harvesters were used by tenants in the Rahad scheme. Ramli found that harvesting cotton by hand rather than machine led to a 121-percent increase in tenant income in Rahad (12). While tenancy sizes were determined based on the availability of family labor, changing off-farm opportunities have reduced family labor participation to the level where less than 50 percent of labor used is family labor (table 4). The extent to which family labor use will increase depends on off-farm occupations and the relative profitability of crops grown within the irrigated schemes.

Most hired laborers who work, especially during the cotton-picking season, are migrant laborers from the rainfed sector in western Sudan. Due to the recent drought, a major shift in population possibly has taken place, with farmers from the rainfed subsector in western Sudan migrating to higher rainfall areas and to the irrigated subsector. As part of the wages of hired laborers is the payment of sorghum, in kind, availability of grain within the subsector and the cash wage rate became important components of the structure of wage incentives for hired labor. In 1985, the bumper sorghum crop in the mechanized sorghum-producing areas in eastern Sudan affected the wage structure as wages for sorghum harvesting increased to LS10 per day from LS4 per day in 1984. This caused labor shortages for cotton picking in the irrigated schemes. The extent to which decisions are made on mechanization of selected operations will also affect the demand for labor and indirectly the productivity of the subsector.

Table 4--Family labor participation by month, Rahad scheme

Month	Family labor as percentage of total labor used in cropping activities
	Percent
June	42
July	41
August	35
September	33
October	39
November	13
December	14
January	5
February	7
March	47
April	45
May	0

Source: (16).

At present, preplanting operations are done with machinery, and other inputs such as chemical fertilizer, insecticide, and pesticide are used predominantly on cotton. Decisions on the quantity of nonlabor inputs to be used are based on physical availability of inputs and agronomic recommendations. These decisions could, in fact, be based upon economic criteria rather than technical criteria only. The lack of tenant freedom to substitute inputs like fertilizer and to vary the level of their use based on economic criteria suggests that a non-optimal allocation of resources may be taking place. Faki (7) estimated optimal levels of fertilizer use for crops in Gezira and compared them with actual levels of use. While fertilizer is currently not used for sorghum and groundnuts due to availability constraints, its use is economical on all crops. However, their recommended economic levels of usage vary with changing world prices.

The role of nonlabor inputs in affecting agricultural productivity needs to be analyzed both from a technical and an economic perspective that includes farming under an institutional arrangement giving tenants the freedom to decide how much to use and the crop on which to use the inputs. It is also possible that foreign exchange constraints at the subsector and macroeconomy level could affect the availability of an imported input like fertilizer at the farm level, causing tenants to resell fertilizer in a parallel market at higher prices. An analysis of the extent to which tenants are charged the true scarcity costs of inputs should be undertaken to determine the effects on agricultural productivity.

Credit is an important input in the production process, especially for cotton. The scheme provides credit to tenants to coincide with major operations like cotton planting, weeding, and harvesting. Recent data indicate that credit provided by the scheme is insufficient in meeting tenants' capital needs (8). Credit for scheme operations is made available to irrigated schemes from the Bank of Sudan. This credit includes not only credit for cash advances for tenant operations, but also credit related to the importation of inputs like fertilizer and financing the exports of cotton. Therefore, credit constraints at the macro level could affect its availability at the scheme and farm level, thereby affecting productivity.

Environmental Factors

In irrigated agriculture, availability of water for irrigation is important for development. Sudan has access to the waters of the Blue, White, and Main Niles, with over 80 percent of the flow in the Main Nile coming from the Blue Nile. This has enabled Sudan to develop irrigated agriculture using the resources of the Blue Nile; over 65 percent of Sudan's irrigated area is fed by the Blue Nile. Together with the water resources, the soil characteristics of the land area between the Blue Nile and the White Nile are conducive to irrigation. In fact, there is potentially another 1.2 million feddan that could be brought under irrigation in the central and southern parts of the country. To do so would require investment in infrastructure, like heightening the Roseires dam, expanding the canal network in Rahad and Gezira schemes, and completing projects like Jonglei.

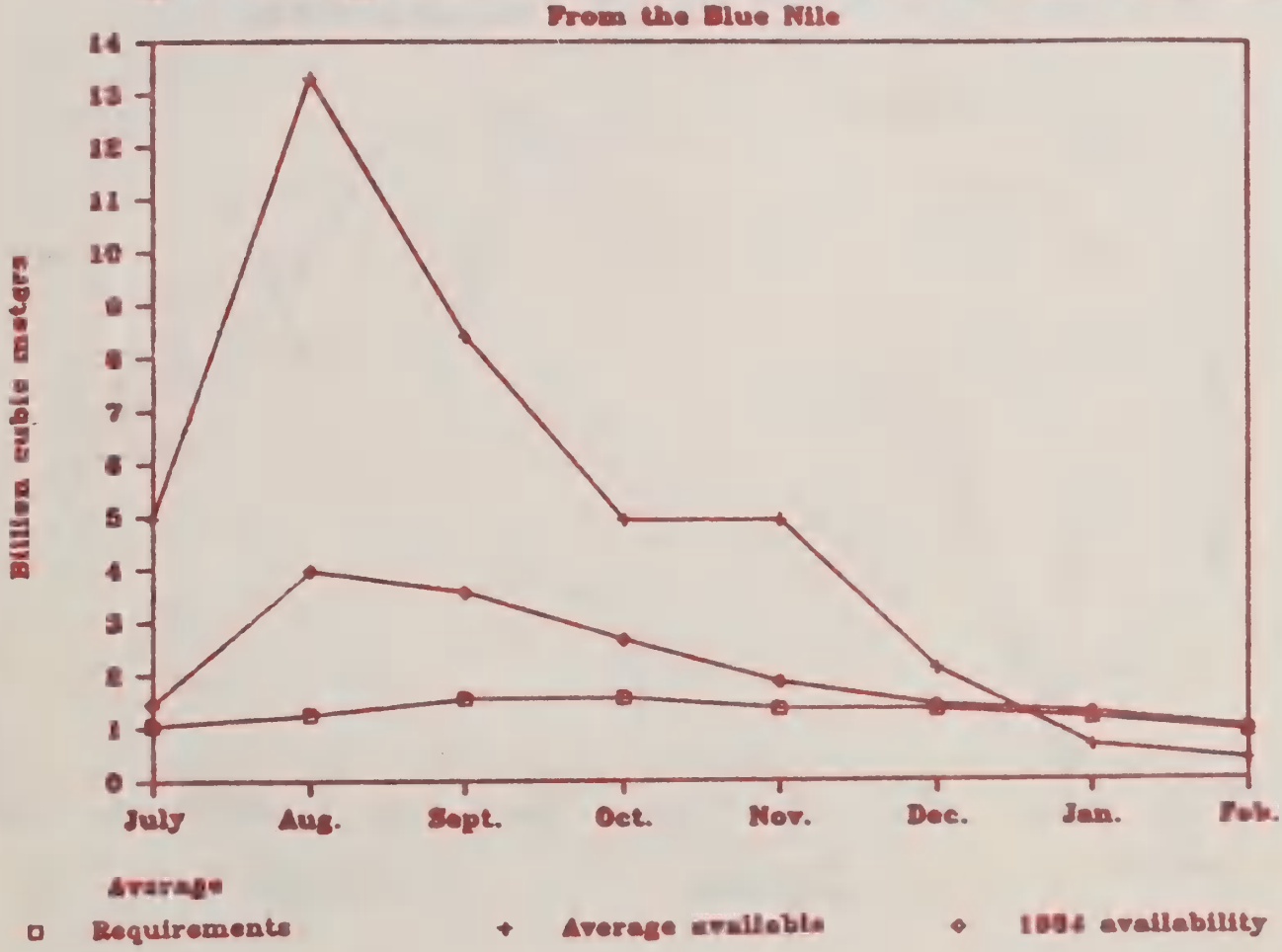
But the Blue Nile depends upon rainfall in Ethiopia to irrigate in Sudan, and it is possible that insufficient rain will affect the river's level, as was seen in 1984/85 when the Blue Nile was at its lowest level since 1913 due to drought in both Ethiopia and Sudan. Figure 8 shows normal flow of the Blue Nile, annual irrigation requirements from the Blue Nile, and the effects on

flow of poor rainfall in 1984/85. The excess of availability over requirements during the months prior to December reflects water that can be stored in reservoirs or water that passes downstream and is made available to Egypt under the Nile waters agreement (4). Between December and March, requirements have to be met by water stored in the reservoirs, but these may be insufficient to meet needs, as seen for the Gezira scheme in figure 9 for the 1983/84 season.

Unlike Egypt, Sudanese agriculture also depends on rainfall, as the area in the major schemes like Rahad and Gezira receive between 260mm and 400mm annually. Most preplanting operations and sorghum planting are done at the onset of the rains. Delays in the onset of the rains affect planting dates, yields, and the availability of irrigation water (table 3).

A combination of the earlier discussed institutional, technical, economic, and environmental factors affects productivity and the production potential of Sudanese irrigated agriculture. These factors affect productivity at the subsector, scheme, and farm levels. Analyzing implications of changes in various policies should be done not only at each level but also in an integrative manner so that tradeoffs in achieving policy objectives may be ascertained. In a later section of this report, issues for policy analysis are discussed in detail.

Fig.8:Irrigation Requirements for Sudan



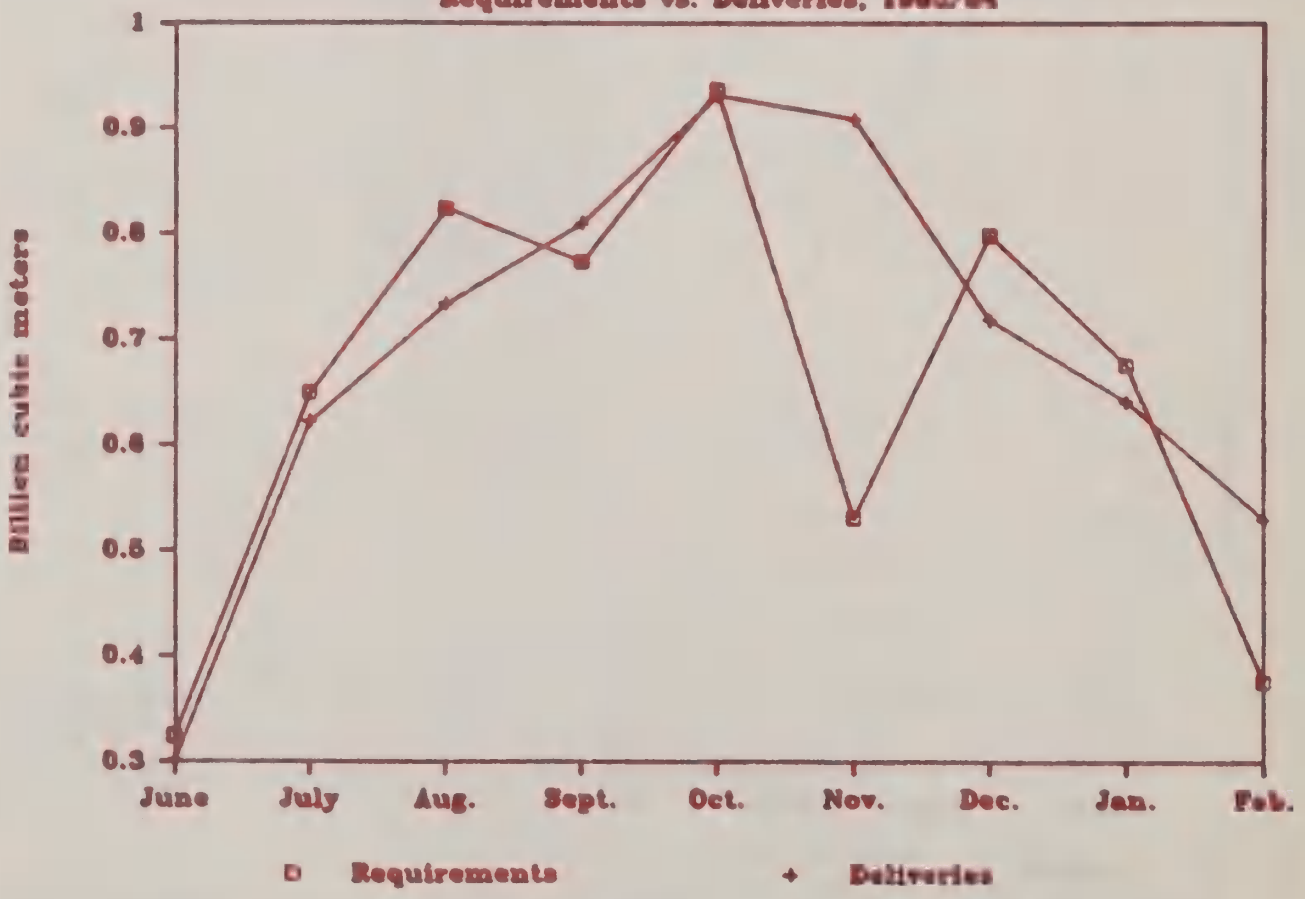
Source: (14).

CAPACITY OF THE IRRIGATED SUBSECTOR TO GENERATE FOREIGN EXCHANGE AND ITS RELATIONSHIP TO THE MACROECONOMY

With an outstanding external debt of over $9 billion and debt service of over $1 billion in 1985, Sudan depends on the generation of foreign exchange for the survival of its economy. On February 3, 1986, Sudan was declared ineligible to receive additional resources from the International Monetary Fund (IMF). This declaration precludes the convening of a Paris club meeting of Sudan's creditors and a rescheduling of its external debt. While imports have declined due to import control measures imposed by the Government of Sudan, exports have also declined due to drought and problems with cotton marketing. As over 90 percent of foreign exchange earnings come from agriculture, any analysis of Sudan's export earnings needs to consider the production and future export earnings potential of Sudanese agriculture. In this report, the focus is on the potential of the irrigated subsector.

The composition of Sudan's agricultural exports and the source of its export earnings changed during 1975-85 (4). Cotton no longer provides over 50 percent of export earnings, even though cotton production has increased in the last 3 years. This is due to problems that Sudan has had in marketing its cotton, a decline in its quality, and the emergence of China as a major exporter in the world market. As Sudan moves into the second half of the eighties, the role of the irrigated subsector in generating foreign exchange needs to be critically evaluated.

Figure 9: Gezira Water Requirements vs. Deliveries, 1983/84

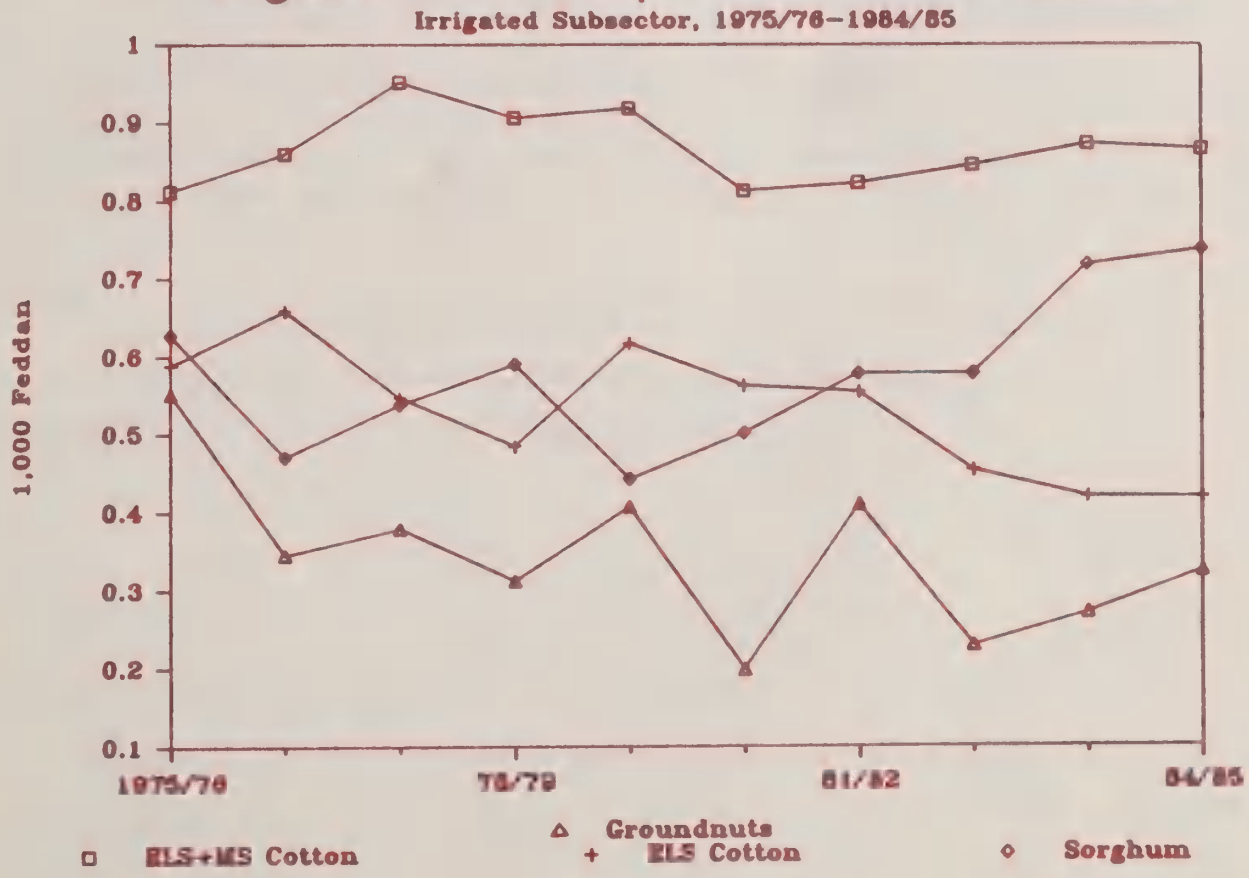


Source: (13).

Historically, the rainfed subsector was viewed as being able to provide the food needs of the country through expansion of mechanized rainfed cultivation, and the irrigated subsector was viewed as being the principal source of foreign exchange earnings. This led to a specific cropping pattern in irrigated schemes as seen earlier in table 1. Furthermore, as over 80 percent of crop area allocations in the irrigated scheme are administratively determined, decisionmakers could reallocate area to different crops within schemes and across schemes (within certain technical and agronomic constraints). Figure 10 shows changing crop area allocations for the subsector between 1975/76 and 1984/85. A decline can be seen in groundnut area planted while sorghum area increased, reflecting changing priorities of tenants and environmental and economic factors.

While overall cotton area has remained stable since the early eighties, a shift has taken place with an increase in MS (medium staple) cotton and a decrease in ELS (extra long staple) cotton area up to a point in 1984/85 where area planted to MS cotton was greater than that planted to ELS cotton. This variability in aggregate crop area allocations reflects implementation of decisions at the subsector, scheme, and tenant levels. For example, perceived labor shortages for cotton harvesting led to a reduction in ELS cotton area in the Gezira scheme, while increased farmgate prices led to increased groundnut area planted between 1982/83 and 1983/84.

Figure 10: Crop Area Allocations



Source: (14).

In evaluating the potential of the irrigated subsector to generate foreign exchange, we need to evaluate the intensity of imported inputs used in the subsector and the potential of crops in the present cropping pattern to generate foreign exchange to determine the implications of changing cropping patterns for foreign exchange use and earnings.

Intensity of Imported Input Use

Fuel and agricultural inputs are major imported goods used in the agricultural sector of Sudan. The share of petroleum products in the import bill was 24 percent in 1983/84. Agriculture is the second largest user of gasoil (diesel fuel) in the economy. The irrigated subsector uses 48 percent of total gasoil used for crop production in the country (4). 8/ Fertilizer, pesticides, insecticides, seeds, jute sacks, and machinery used in the irrigated subsector are also imported. Table 5 shows the value and share of agricultural inputs as a percentage of total imports for 1980/81-1984/85. Machinery and jute sacks are also used in the mechanized rainfed areas.

The intensity of imported input use varies by crop, as seen in table 6. In schemes like Gezira, cotton shows the highest ratio of imported input use to value of output. In addition to the intensity of imported input use, other economic measures of both a crop's contribution to foreign exchange and its use of domestic resources exist. These are international value added (IVA) and domestic resource cost (DRC) ratios. IVA measures the net contribution to foreign exchange earnings per unit of standard input, like land. The DRC ratio measures the ratio of domestic resources used in the production process per unit of IVA.

Table 5--Agricultural inputs, excluding petroleum products, compared with total imports, Sudan

Year	Total imports	Agricultural inputs imported	Share
	-----Million dollars-----		Percent
1980/81	1,569	171	11
1981/82	1,774	158	9
1982/83	1,516	148	10
1983/84	1,388	133	10
1984/85	1,211	132	11

Source: (2).

8/ This does not include fuel used for vehicles of individuals, like field inspectors, who work within the irrigated schemes.

Changing Domestic Resource Cost Ratios

Measures like IVA and DRC ratios are often used to analyze the relative competitiveness of crops in world markets and their relative potential in generating foreign exchange. However, while these measures are indicators of competitiveness, they should be used carefully because their computation requires assumptions concerning yield levels and input and output prices, as well as structure and costs of production. Furthermore, these coefficients are usually computed for a single time period and in a partial equilibrium framework. In an economy like Sudan's that experienced high rates of inflation, a comparison of the relative ranking of DRC ratios over time is more meaningful than their numerical values.

Table 7 shows changes in DRC ratios and the relative rankings computed for the major crops for different time periods in the Sudan. (The lower the absolute value of the DRC ratio, the higher its comparative advantage as a foreign exchange earner.) The DRC ratios vary by time and across subsector, with groundnuts ranking high in competitiveness. In recent years, the competitive position of irrigated subsector crops, especially cotton and wheat, has declined while that of sorghum and groundnuts has improved. The introduction of a hybrid sorghum variety, which has increased yields by 400 percent in the irrigated areas, will change the competitive position of irrigated sorghum.

As Sudan has limited foreign exchange and limited access to foreign exchange through world capital markets, it has to depend on export earnings and external aid to finance the inputs it needs. This situation places a high premium on allocation of scarce foreign exchange resources. Historically, the irrigated subsector financed its imported input needs through export earnings. But problems with the quality of cotton produced, causing the inability to sell cotton (with stocks of over 1.5 million bales), has led to an uneconomic allocation of scarce foreign exchange as dollars expended on cotton inputs have not generated commensurate incremental increases in foreign exchange in the last 3 years.

Table 6--Intensity of imported input use in irrigated agriculture by crop, Sudan

Crop	Ratio of value of traded inputs to value of output 1/
Wheat	0.60
Cotton (ELS) 2/	.57
Cotton (MS) 3/	.55
Sorghum	.21
Groundnuts	.15

1/ Based on data for all crops in the Gezira scheme, 1983/84. The same exchange rate was used to value inputs and outputs.
2/ ELS = extra long staple.
3/ MS = medium staple.

Source: (13).

The competitiveness of Sudan's agricultural exports and their potential export earnings, even as measured by DRC ratios, depends on the exchange rate regime. This is especially true for irrigated subsector crops with a higher intensity of imported input use. The multiplicity of exchange rates and differential valuation of agricultural inputs and exports in Sudan also affect

Table 7--Domestic resource cost ratios and relative rankings for major crops grown in Sudan, by subsector, selected years 1/

Crop and location	Domestic resource cost ratio			
	1976/77	1980/81	1981/82	1983/84
Groundnuts:				
Irrigated	0.41	0.74	0.37	0.80
	(3)	(3)	(1)	(1)
Traditional rainfed	.31	.45	.39	1.00
	(1)	(1)	(2)	(2)
Sorghum:				
Mechanized rainfed	.68	.42	1.28	1.28
	(5)	(2)	(9)	(3)
Traditional rainfed	.37	1.05	.42	--
	(2)	(7)	(3)	
Irrigated	.75	.83	.53	1.41
	(6)	(5)	(4)	(6)
Cotton, MS 2/ irrigated:				
Rahad scheme	--	--	.55	1.47
			(5)	(7)
Gezira scheme	.45	.79	.71	1.36
	(4)	(4)	(7)	(5)
Cotton, ELS 3/ irrigated:				
Gezira scheme	.37	.84	.89	1.35
	(2)	(6)	(8)	(4)
Wheat, irrigated:				
Gezira scheme	--	--	.68	2.06
			(6)	(8)

-- = Not calculated.

1/ Numbers in parentheses are ordered rankings of crops and locations by competitiveness.

2/ MS = medium staple.

3/ ELS = extra long staple.

Sources: For 1976/77 data see (11), for 1980/81 data see (15). The 1981/82 and 1983/84 data were computed from (14).

the competitive ranking of crops, as shown in an illustrative crop budget for irrigated sorghum in table 8. 9/

Table 8--Impact of changing yield levels and exchange rates on export competitiveness of irrigated sorghum, Sudan

Item	Unit	Base case (traditional variety, no exchange rate change)	Alternative cases			
			Hybrid with exchange rate change			Hybrid with no exchange rate change
Yield	Tons/feddan	0.63	1.98	1.98	1.98	1.98
Exchange rate	LS per $	2.5	3.3	3.5	4.0	2.5
Costs of production	LS per ton	317	122	122	122	122
Marketing cost	LS per ton	271	271	271	271	271
Total cost: Port Sudan	LS per ton	588	393	393	393	393
Value of output:						
$150 per ton	LS per ton	375	493	525	600	375
$110 per ton	LS per ton	275	363	385	440	275
Margin of profit:						
$150 per ton	LS per ton	-213	102	132	207	-18
$110 per ton	LS per ton	-313	-30	-8	47	-118

Note: Value of output is calculated at illustrative Saudi Arabian prices of $150 per ton and $110 per ton, including premium.

9/ Sudan has had a variety of exchange rate regimes, and several devaluations have taken place over the last 5 years. In 1980, 1 Sudanese pound was valued at $2.80, while in 1986 LS2.5 = 1 dollar at the official rate, and the street rate was LS5 per dollar. All cotton and gum Arabic exports and inputs like fertilizer and jute sacks are valued at LS2.5 per dollar, while other agricultural exports are valued at an effective rate of LS3.0 per dollar.

Thailand is a major competitor of Sudan in the Saudi Arabian sorghum market. While Saudi Arabia traditionally has provided a subsidy for Sudanese sorghum exports, it is the yield differential of the hybrid sorghum together with a change in the exchange rate that enables Sudan to compete with Thailand's sorghum, which can be imported into Saudi Arabia at $110 per ton.

The introduction of the hybrid sorghum in the irrigated areas could have a major impact on crop area allocations and potential foreign exchange earnings of the subsector. As groundnuts and sorghum rank low in their intensity of imported input use and rank high in their potential contribution to foreign exchange earnings, changing crop area allocations across the subsector could have implications for use of scarce foreign exchange as well as the generation of foreign exchange earnings.

In an optimum equilibrium allocation of crops, the DRC ratios of all crops would be equal (inclusive of all accounting for externalities which may arise in intercrop interactions). Hence, the IVA earned per unit of DRC would be equal for all activities (3).

RELATIONSHIP BETWEEN THE IRRIGATED SUBSECTOR AND THE TRADITIONAL AND MECHANIZED RAINFED SUBSECTORS

As the structure and organization of agricultural production activities vary across the three subsectors (irrigated, mechanized rainfed, and traditional rainfed) of Sudanese agriculture, policy changes not only can have a differential effect across subsectors but can also influence resource flows between subsectors (4). The relationship between subsectors may be analyzed with respect to: competition for inputs like fuel, machinery, and labor, and competition for investment resources (both, public and private), which could enhance the productive capacity of the agricultural sector.

Competition for Inputs

The irrigated and mechanized rainfed subsectors use fuel and machinery, which are imported commodities. As foreign exchange to procure these inputs and domestic fuel are allocated at the national level, the needs of the two subsectors conflict due to a scarcity of foreign exchange. (A move to introduce the privatization of imports and distribution of petroleum products was initiated in 1985 but has recently been curtailed.)

In 1983, the mechanized subsector consumed 8.2 million gallons of gasoil for sorghum, primarily for planting, while irrigated cotton consumed 3.6 million gallons of gasoil (4). While the overall area planted in the irrigated subsector has remained fairly stable, area planted in the mechanized rainfed subsector has varied with rainfall and prices. The 1985/86 bumper sorghum crop in Sudan can be directly linked to the availability of gasoil in the country, primarily through foreign aid, in May and June 1985 (in time for the planting season). The Ministry of Agriculture in Khartoum has estimated that area planted to sorghum in the mechanized subsector of eastern Sudan increased from 4.5 million feddan in 1984/85 to 8.5 million feddan in 1985/86, an increase of 90 percent. This increase would require an estimated additional 5.21 million gallons of gasoil, or 30 percent of total consumption of the entire agricultural sector.

As fuel allocations are made administratively at the national level, sufficient fuel existed in the country for both the mechanized and irrigated subsectors. But due to the deteriorating macroeconomic environment, Sudan will be unable to commercially import crude oil even with declining world crude oil prices. Authorities are faced with a situation of allocation of scarce fuel between two subsectors, both of which have the potential to generate foreign exchange for the country.

Labor in the traditional rainfed subsector migrates to the irrigated subsector for cotton picking and the mechanized subsector for sorghum harvesting. However, the recent drought led to shifts in the distribution of population within the subsector through migration (4). This recent occurrence and the demand for labor in the mechanized rainfed subsector led to shortages of labor in 1985/86 for both cotton and sorghum harvesting. Whether this will be a temporary or long-term phenomenon will depend upon the recurrence of drought in western Sudan, the potential of changing cropping patterns in the irrigated subsector, and the extent to which the area planted in the mechanized rainfed subsector seen in 1985 will continue in future years.

Competition for Investment Resources

Because all three subsectors have the potential for generating foreign exchange revenues, competition exists between subsectors for scarce investment resources. In the past, the primary source of investment resources in the irrigated subsector has been the Government, while the mechanized subsector has developed primarily through private capital, low land rents, and subsidized fuel and machinery prices. However, given the area covered by the mechanized subsector, with an average farm size of 10,000 feddan and with some farms being as large as 100,000 feddan, investment costs could be substantial. In 1983/84, investment costs, primarily tree clearing, to start a 10,000-feddan farm in the mechanized subsector were estimated at over LS200,000, while costs of production were estimated at LS20 per feddan, including a subsidy of approximately 50 percent (10). In addition to individually owned farms, corporations with stockholders from Middle Eastern countries, Saudi Arabia, and Egypt have invested in large farms in the mechanized subsector. The largest of these farms covers an area of 1 million feddan. Minimal capital investment is in the traditional rainfed subsector, primarily consisting of small individually owned and operated farms with low capital resource bases. Even though this subsector contributes to the foreign exchange earnings of the country (4), it has been relatively neglected by both the Government and private capital.

Due to the economic crisis facing the country, future allocations of scarce capital for investment and funds for recurrent expenditure of new projects become important policy issues, not only for the Government but also for donors. Among the two major donors, the World Bank has expended over $300 million in the irrigated subsector since 1979, and the U.S. Agency for International Development has planned to spend over $120 million and LS380 million in the traditional and mechanized subsectors in western Sudan between 1985 and 1990. As the Government will have to cover recurrent costs for these and future investment activities, the comparative earnings potential of each of the subsectors needs to be analyzed.

The DRC ratios shown in table 7 suggest that rainfed subsector crops will have a higher return in foreign exchange than cotton and wheat in the irrigated subsector. But changing cropping patterns in the irrigated subsector could

change these results, as the traditional rainfed subsector is still suffering from the aftermath of drought. In the immediate future, the irrigated subsector holds the potential for sustained production and foreign exchange earnings. But realizing this potential will require policymakers to choose among an array of policy options that could affect cropping patterns, input use, technological and institutional change, and the structure of economic incentives in the irrigated subsector.

ISSUES FOR POLICY ANALYSIS IN THE SUBSECTOR

Due to the existence of an infrastructure within the irrigated subsector, its location, and its administrative organization, this subsector could respond to economic incentives in the short run as it produces three export crops and does not have to recover from the after-effects of a drought. Crucial to its capability to respond is the issue of changing cropping patterns within the subsector.

Analyzing Implications of Changing Cropping Patterns at the Subsector, Scheme, and Farm Levels

Cropping patterns in Sudan's irrigated subsector are determined administratively due to historical reasons related to the development of irrigated schemes. Among the reasons often cited for this practice are: (1) the need to follow a predetermined crop rotation to maintain fertility of the soil, (2) the need to effectively use machinery available for primary operations such as land preparation, (3) the need for uniform application of pesticides through aerial spraying for cotton, and (4) the effective distribution of water through the irrigation network.

While the above reasons are technical in nature, economics has been neglected in decisions concerning crop area allocations. While these decisions cannot be based solely on economic rationale, they also need not be based solely on technical, agronomic criteria. An effort is needed to incorporate economics as one of the criteria in the allocation of crop areas both within and across irrigated schemes in Sudan. This discussion on how to implement these decisions covers the rationale and the implications of introducing economic criteria in allocating crop areas.

The Rationale

Sudan's unsold stock of cotton could increase to 2 million bales after the 1985/86 crop is harvested as prospects for sale of the present crop seem dim due to poor quality. (The 1986 crop showed the heaviest white fly infestation in 3 years.) These large carryover stocks represent not only a loss in valuable foreign exchange from exports, but also a loss in the value of imported inputs used to produce this cotton as they could have been used for other export crops. At a time of severe economic crisis and a decline in the value of export earnings, Sudan cannot afford to misallocate foreign exchange or forgo foreign exchange earnings. The opportunity cost of foreign exchange used for inputs is indeed very high.

A discussion of the opportunity cost of foreign exchange used to finance inputs for the irrigated subsector leads to the manner in which area allocation decisions are determined in the subsector. The present manner of determining crop area allocations without reference to the role of relative

prices on both the input and output sides suggests that an inefficient allocation of resources could be taking place, both within and across schemes. For example, medium staple cotton is grown both within the Rahad and Gezira schemes. However, yields of MS cotton have been higher in Rahad (7.1 Kantar/feddan) than in Gezira (6.5 Kantar/feddan) (fig. 7). Since the per-feddan costs of production are nearly equal, MS cotton should be produced in Rahad; but continuing to allocate area in Gezira to MS cotton instead of other crops at a time of declining world prices for MS cotton and in a market where Sudan is a price taker would be a poor economic decision. Of course, the Government of Sudan could argue that imported inputs for the irrigated subsector have been acquired through aid agencies and as part of the rehabilitation program funded by the World Bank, rather than out of export earnings. But still, the opportunity cost of foreign exchange, acquired either through aid or as credit, used for the irrigated subsector needs to be critically analyzed.

Implications of Changing Crop Area Allocations

Irrigated crop area allocations take place at the subsector level (across schemes), the scheme level (within schemes), and even at the individual farm level. The implications at all three levels will be examined.

At the subsector level. Should the present administrative allocation system continue across the subsector, decisions should at least be made on the principle of comparative advantage within the subsector. This will allow specialization of schemes in crops in which they are productive given their relative resource levels. Determining such decisions can usually be undertaken in a market environment where relative prices determine allocation decisions. But Sudan's irrigated subsector does not operate in an environment of free mobility of resources and freely fluctuating input and output prices.

Given the shortage of foreign exchange and the need to generate foreign exchange, the question can be raised: If a dollar is not spent in the irrigated subsector, where will it be spent? Given the response potential of dryland agriculture (as was seen in the 1985/86 season), scarce foreign exchange used as a result of changing cropping patterns in the irrigated subsector could generate greater foreign exchange earnings from the dryland areas. For example, a shortage of groundnut seed will drastically affect groundnut production in Sudan, seed that could have been purchased using foreign exchange saved from changes in cropping patterns in the irrigated subsector.

Specifically, the implications of reducing MS cotton area in the irrigated subsector can be analyzed. Cotton production requires fertilizer, machinery, insecticides, herbicides, water, and labor as key inputs. Of these, fertilizer, machinery, insecticides, and herbicides are imported and constitute over 50 percent of total costs per feddan. Water availability depends on the Blue and White Niles systems and most of the labor used for cotton picking comes from outside the subsector. Reduction in cotton area reduces use of all of these inputs and could have implications for increasing productivity both within and outside the subsector. As cotton and wheat compete for irrigation water during November to March, reducing the cotton area will increase the availability of water for wheat, which could lead to increased wheat productivity. (Wheat productivity in Sudan is determined by the planting date, availability of irrigation water, use of fertilizer, and the procurement price.)

Similarly, a reduction in cotton area could lead to increased availability of gasoil machinery services and fertilizer for other crops. For example, in 1985/86, farmers in the Gezira scheme were being given fertilizer to use on hybrid sorghum (Hageen Dura-1). With the success of the hybrid sorghum, use of fertilizer will lead to higher yields and make Sudan competitive in the Saudi Arabian sorghum market and generate incremental foreign exchange (table 8). 10/ In 1985/86, farmers in Gezira reported receiving over 22 sacks of sorghum/feddan of Hageen Dura-1, compared with 7 sacks of the traditional variety. The hybrid variety also yielded 12 sacks/feddan in the mechanized areas of Gedaref compared with 4 sacks/feddan for the traditional variety. The yield differential is sufficient to cover the added costs of using fertilizer for Hageen Dura-1, both in the irrigated subsector and the mechanized rainfed subsector. Because the mechanized subsector is short of labor, increased gasoil availability could have a higher payoff than fertilizer availability.

Physical labor shortages exist in the mechanized and irrigated subsectors for harvesting sorghum and cotton. While increased wages could lead to a reallocation of labor across subsectors, reduction in cotton area could lead to increased physical availability of labor for both sorghum and cotton harvesting. Migrants from western Sudan who work as cotton pickers in the irrigated subsector get paid food in kind (sorghum) as well as a cash wage. Increased sorghum availability in the irrigated subsector (and in the country) will allow tenants to pay cotton pickers sorghum (sorghum in kind) in addition to the cash wage rather than sell the sorghum in the market as in 1984/85.

Cotton also requires credit during the production process. At present, a line of credit is extended by the Bank of Sudan to the various schemes in the irrigated subsector. Credit is then extended by schemes to all tenants for planting, weeding, and harvesting operations. 11/

This credit is, however, insufficient to meet the operating capital needs of tenants who view cotton not as their crop but that of the Government and, hence, are usually unwilling to finance its production. This leads tenants, suffering from capital constraints, to shail or mortgage their other crops, like groundnuts, wheat, and sorghum. 12/ As repayment of shail credit takes place in kind and at a price agreed to prior to harvest, interest rates could be over 150 percent. A tenant with a low resource base may be unable to undertake operations on time thereby affecting crop productivity and incomes. (Tenants' credit payments are deducted from their individual account, and if their yields are greater than the break-even level, they are given the net revenues as income from cotton. Otherwise, they accumulated debts with the scheme, and a continued accumulation of debt could lead to loss of the tenancy.)

10/ Prior to 1985/86, fertilizer use in the irrigated subsector was restricted to cotton and wheat.

11/ It may be argued that as the Bank of Sudan receives revenues from Cotton Public Corporation sales, extended credit should be viewed not as a subsidy but an additional cost of producing foreign exchange. If so, this should be incorporated in comparative analysis of irrigated and rainfed agriculture, net foreign exchange earnings, and domestic resource costs for different crops.

12/ Shail is a system through which farmers acquire informal credit through mortgaging crops already planted. Ahmed found that interest rates under shail can range between 100 and 300 percent (1).

A review of the financial accounts of five schemes (Gezira, Rahad, New Halfa, White Nile, and Blue Nile) shows that the line of credit extended by the Bank of Sudan has been insufficient to meet not only the credit needs of the tenants but also the individual account revenues. This requires an additional line of credit from the Bank of Sudan to the five schemes at the end of the season to pay tenants their income from cotton. As the schemes do not repay this line of credit, which may be viewed as a subsidy from the Government to the schemes, this cumulative transfer has increased to over LS300 million over the past 5 years. Reduction in cotton area will reduce the need for this line of credit and the credit requirements of the schemes. This could also lead to a reduction in the practice of shail in the schemes, increasing tenant incomes.

At the scheme level. With the present size of irrigated schemes (for example, 2.1 million feddan in Gezira and 300,000 feddan in Rahad), variability within schemes exists in soil type, infrastructure, access to market, and inputs like water. Yet, cropping patterns and rotations are mostly uniform. In the Old Gezira (Gezira Main), a four-course rotation is practiced which includes a fallow, while in the New Gezira (the Managil Extension) a three-course rotation does not include a fallow. This variability within schemes has led to variability in yields production (figs. 5 and 6). Under the individual account system, a minimum yield of cotton is required before tenants receive any income, which suggests that no allowance is made for variability in production due to technical factors beyond the tenants' control. This leads to a situation where tenants, unable to achieve a minimum yield level, incur an accumulating debt with the scheme since they are required to grow cotton.

Changing cropping patterns and reallocating area within each of the schemes should also be undertaken on the principle of comparative advantage. Scheme management should learn from the actions of tenants: for example, when the Rahad scheme was initiated in 1977/78 sorghum was not in the cropping pattern, but, due to the pressure of tenants, sorghum was subsequently introduced into the cropping pattern up to the point where tenants now plant between 25 and 50 percent of the total area to sorghum because of its importance in their diet and its use as a wage good.

Within-scheme constraints should also be taken into consideration when area allocation decisions are made. For example, reducing cotton area in Gezira, specifically reducing MS area, will lead to increased water availability for other crops such as wheat and long staple cotton. (The capacity of the main irrigation canals is a major factor affecting cropping area allocation in Gezira.) An analysis of water releases from Sennar for Gezira during the crucial October/November to February/March period as compared with water requirements based on actual cropping patterns indicates shortages for all but one of the years from 1965/66 to 1983/84 (5). This was primarily due to the capacity of the main Gezira canals. A similar rationale for reducing cotton area across the subsector holds for reducing area within schemes.

At the farm level. The determination of crop area allocations at the farm level is imposed by scheme management with minimal flexibility for tenants to respond to changing economic incentives. Tenants do in some schemes attempt to modify scheme-dictated cropping patterns by reallocating areas between groundnuts and sorghum. However, as cotton requires the highest labor and capital input per unit area, requiring tenants to grow fixed areas of cotton does not allow them to allocate their scarce labor and capital in areas with the highest net return. Furthermore, since farmers' use of fertilizer until

recently was restricted to cotton and wheat, their allocation at the farm level was less than optimal from an economic prespective. Reducing cotton area at the scheme level will, in effect, allow tenants greater flexibility in decisionmaking at the farm level. Availability of fertilizer could increase, and farmers could be using their scarce labor, capital, and fertilizer more economically. For instance, considerable potential exists for increasing groundnut and hybrid sorghum in the irrigated areas, both of which could lead to increased foreign exchange earnings and to reduced imported input use. Also, as sorghum and groundnut prices are market- rather than scheme-determined, introducing greater flexibility could lead to prices rather than administrative fiat determining area allocation decisions at the farm level.

Analyzing Implications of Technological Change within the Subsector

Technological change could affect aggregate supply response and the demand for both traded and nontraded inputs from the subsector. The extent to which technological change takes place would depend upon a variety of factors as discussed earlier in this report. Technological change, such as the adoption of mechanical groundnut harvesters and mechanical cotton harvesters, could affect not only productivity and aggregate supply response within the subsector, but also the mix of inputs used. Similarly, the use of chemicals like fertilizers, herbicides, and pesticides could also affect input demand and supply response. However, if the country is faced with a foreign exchange constraint at the macro level and if the use of technologies requires scarce foreign exchange, then decisionmakers are faced with options concerning allocation of foreign exchange to competing technologies. Valuing resources at their opportunity cost becomes crucial in such an analysis, especially using the appropriate shadow rate of foreign exchange for imported inputs. This would enable decisionmakers to analyze tradeoffs between choices of different chemical and mechanical technologies.

Increased adoption of mechanical laborsaving technologies suggests that they reduce labor bottlenecks and increase productivity. However, the relative costs of mechanical technologies should be compared with task-specific wage rates for the operations in which they are used. For example, from a tenant's perspective, use of a groundnut harvester reduces the demand for labor at a peak period and also leads to increased yields. As the tenant pays the scheme a fixed cost for use of the harvester, the tenant compares the wage rate and efficiency of hired labor with the cost for using the harvester.

The recent increase in the demand for groundnut harvesters in the Rahad scheme suggests that tenants find it economical to use groundnut harvesters. Similarly, choice of different technologies would affect the market for labor. Increased use of herbicides would reduce the demand for weeding labor as would increased use of groundnut and cotton harvesters. Use of chemical and mechanical technologies could also affect crop productivity and aggregate supply response, as crucial operations would take place on time.

Increased demand at the farm level can be met only through availability of harvesters at the scheme and subsector levels. At present, the Rahad scheme has insufficient groundnut harvesters, and they are not used in the Gezira scheme because of a lack of foreign exchange to import these items. Subsectoral- and scheme-level constraints could affect choice of technology and productivity at the farm level.

Analyzing Implications of Institutional Change within the Subsector

The introduction of the individual account system was considered a major institutional change because it allowed for crop specific incentives, and it also served as a system of cost recovery for the schemes. While recent evidence suggests that cotton yields have increased, the system through which fixed costs are transmitted to tenants may affect the distribution of incomes within schemes and farm-level productivity. This is primarily due to variability in infrastructure, soils, and access to water within large schemes like Gezira.

The individual account system could also be used to transfer incentives that reflect subsectoral- and scheme-level priorities, conflicting with tenant priorities. For example, if the full effects of devaluations are transmitted only on the input side and not on the output side, the relative profitability of crops under the present institutional system could change, thereby affecting tenants' allocation of their labor and capital. However, if other institutional changes are introduced, such as freeing tenant decisionmaking concerning crop area allocations and using fertilizer and herbicide, and if the complete effects of devaluations are transmitted, then the viability of the individual account will be enhanced as a major institutional change. As in the case of changing crop area allocations and technological change, institutional change has implications at the subsector, scheme, and farm levels.

Subsectoral objectives are related to the maximization of export earnings and increasing Government revenues, primarily through export and import taxes. The Government could impose an implicit tax on producers by not passing the incentive effect of a devaluation on the output side. In Sudan, cotton has played an important role in generating Government revenues and foreign exchange earnings. By controlling the prices of output and of important inputs, the Government, in effect, determines the level of relative profitability of irrigated subsector crops. By influencing decisions on area to be planted to cotton, the Government could, in effect, determine the magnitude of tax revenues that could be generated from cotton and other irrigated subsector crops. The individual account system could be used as a way of transmitting world price changes, both on the input and output sides, to the scheme and farm levels. This will affect the relative profitability of crops and could lead to reduced yields for crops like MS cotton. In addition to transmitting world prices, tenant flexibility should be increased so that the tenant can respond to changing incentives as should the schemes and subsectors. At present, conflicting objectives exist between the Government (at the subsector level), schemes and tenants. Evaluation of tradeoffs among these objectives is necessary to quantify the effect of alternative institutional arrangements within the subsector.

CONCLUSIONS

Sudan's present economic crisis suggests a need for evaluating the role of its irrigated subsector, the largest in Sub-Saharan Africa, in agricultural and economic recovery. Due to changes in world market conditions, the competitive position of an irrigated subsector crop like MS cotton has declined while improved technology, primarily a hybrid seed, has improved the competitive position of sorghum. These changes require an analysis of the implications of

changing cropping patterns within the subsector where crops are grown on the basis of the principle of comparative advantage across and within schemes.

Related to an analysis of cropping patterns is the need for analyzing implications of different institutional arrangements within the subsector, which would enable tenants to respond to changing world economic conditions and domestic policy shifts. The present system of irrigated subsector production leads to a suboptimal use of inputs like fertilizer and affects demand for mechanical technologies like groundnut and cotton harvesters. If Sudan's irrigated subsector is to be viewed as a key to economic recovery in the next 3 to 5 years, analyzing the implications of changing cropping patterns and of institutional and technological change will shed light on the prospects of using the subsector to generate increased foreign exchange earnings, Government revenues, and tenant incomes. This will enable us to determine the extent to which the subsector could regain its role as a major provider of export earnings for the country.

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*U.S.GOVERNMENT PRINTING OFFICE:1986-490-917:40039/ERS